THE DELTA AND ITS RESOURCES

GENERAL OVERVIEW

The word "delta" in the region of the Mississippi River has come to represent many different ideas. According to the Lower Mississippi Delta Region Initiatives it includes a total of 308 counties and parishes in Illinois, Kentucky, Missouri, and Tennessee as well as the entire states of Arkansas, Louisiana, and Mississippi (see the Study Area map at the beginning of the document). This political definition has little to do with the natural boundaries of the resources that define the delta.

In natural resource terms, the Mississippi Delta is the alluvial valley stretching from southern Illinois to central Louisiana at the junction of the Red, Atchafalaya, and Mississippi Rivers. Geologically, this was a deep valley eroded by the Mississippi during the Pleistocene when the sea level was 200 feet below its present stand. After the Ice Age, as the sea level rose, the river filled this old valley with alluvium. At the time of settlement, the Delta was an area of alluvial soils occupying a valley between higher terraces to the east and west. The soils were subject to the annual overflow of the Mississippi River and its many tributaries.

Another common usage of "delta" refers to the "recent delta" — that area of new land built by the Mississippi onto the continental shelf in approximately the last 5,000 years. The "true delta" is essentially the new land built by alluvium after the valley delta was filled. The river occupied seven different deltas (deltaic lobes) and more than 30 main channels in the process of building the "recent delta," all in south-central and southeast Louisiana. The most recent of the deltaic lobes is also referred to as the "delta" or sometimes the "modern" or "bird's foot" delta and is the area below New Orleans at the present mouth of the river where the channel forks into the various passes.

The Lower Mississippi Delta (hereafter referred to as the Delta), regardless of the definition used, is a vast and vital part of the American landscape. This broad, alluvial valley provides habitat and ecological support for a wide variety of flora, fauna, and aquatic species integral to health of the north American continent. The Mississippi River forms the most important bird and waterfowl migration corridor on the continent. The river bottoms comprise North America's largest wetland area and bottomland hardwood forest. More than 20% of the nation's duck population migrates along the river and one-third of the freshwater fish species in North America live in the river.

In addition to the bottomland hardwood forests in the Delta, the expanded area covered by the study area is also home to upland forests of deciduous and coniferous varieties. They are found in the hills and elevated tracts.

The dynamic character of the Delta's ever-changing natural processes are found in a variety of fascinating events — the New Madrid earthquakes of 1811–1812, the devastating flood of 1927, and the geologic curiosity of Crowley's Ridge. The region's national natural landmarks and state natural areas all attest to the natural processes at work in the Delta.

Human manipulation of the environment as a response to these natural processes or as expressions of cultural beliefs can be seen across the Delta landscape. From Poverty Point's massive effigy earthworks and adjacent dwelling sites to the monumental flood control devises on the Mississippi River today, natural resources have been used over and over again for ritual, survival, trade, and/or profit.

American Indian agricultural practices were probably the single greatest environmental influence before European colonization. Slash-and-burn farming techniques eventually gave way to intensive maize cultivation. This emergence of maize-based food production changed the social and political fabric of Mississippian society. As they began to rely on more centralized authority and economic redistribution, their dependence on local resources increased and brought pressure on local resource stores in the surrounding forests, streams, and coastal fisheries. However, the long-term effects these early Indian groups had on the environment pales in comparison with the Euroamerican settlements that followed. Most of the remains of the mound building societies have faded from the landscape or have been bulldozed into the land with the technological advances of the last two centuries.

The water-control projects of the Mississippi River and its tributaries are man-made wonders within the Delta. The dams, levees, cutoffs, diversions, and other water-control facilities, like the Atchafalaya diversion structures and the Caernarvon freshwater structure of southern Louisiana, are marvels of engineering. The structures are often monumental in size, enormously complex in engineering, and are substantial in their effect on the natural environment.

The Delta's renowned agricultural productivity is a direct reflection of the region's fertile alluvial soils, the temperate climate (average yearly temperature of 54-65°F), and the extended growing seasons (200-340 days of frost-free weather annually). Much of the nation's soybeans, rice, sugar cane, feed grains, and cotton are produced on Delta farms. Between 55% and 60% of the land area in the Delta is utilized as cropland. By comparison elevated portions of the region use between 6% and 40% of available land area for crops.

Natural resources have been extracted from the Delta since before European settlement. Evidence shows Indian groups traded throughout much of the north American continent. Deposits of salt, coal, and native clay soil have been exploited for use by successive generations of the Delta's human inhabitants. Oil and gas exploration began shortly after the turn of the 20th century and now oil and gas wells, petro-chemical manufacturing plants, paper mills, sugar refineries, and sewage treat-ment plants dot the landscape.

Water quality has been and continues to be the prime pollution concern for the Delta. The extensive water pollution has resulted from years of discharging petrochemicals, municipal sewage and wastewater, and farm chemical runoff into the watershed. In addition the deforestation and loss of wetland habitat through much of the region has added to poor water quality.

Cleanup efforts on the Mississippi River, its tributaries and its critical habitats have been a primary concern for local residents, state and federal government agencies, and regional environmental groups. Laws and regulations as well as changes in public attitudes toward the natural environment and its importance for human survival have led to steady improvements in the Delta.

GEOLOGY

About 18,000 years ago a continental glacier covered North America. This continental glaciation event, with its gradual melting period from 12,000 to 7,500 years ago, was the last in a series of continental glaciers that have formed and then receded over the last 25 million years. Although no glacier reached the lower Mississippi Delta region its influences have forged and transformed the surrounding lands.

As the glaciers melted and reformed, the Mississippi and its tributaries carved valleys and created floodplains across the region. The floodplains and river valleys were further altered by changes in sea level over time. These changes created the terraces that mark the region today. As the glaciers receded, runoff increased to five times the volume of today's rivers and streams. High waterflow combined with high sediment loads of the glacial meltwaters created a braided stream patter along the Mississippi, Ohio, and other streams (Saucier 1994).

As the volume of water discharged into the Mississippi valley dropped, the Mississippi River flow evolved into its existing meandering pattern.

The continental glaciers had gouged out millions of tons of bedrock and crushed and weathered the rock into various types of sediment, the largest amounts being silt and sand. The resulting sediment in the form of loess deposits (wind-transported deposits) and fluvial deposits (water-transported deposits) were transported from north and west of the region were redeposited within the Delta in layers tens of meters thick. The Delta's surface topography is a result of these deposits from the glaciers.

At the confluence of the Ohio and Mississippi Rivers the average floodplain elevation is approximately 325 feet. At sea level on the Gulf of Mexico, the Mississippi River averages an elevation drop of less than a foot per mile for extended stretches of 10 or more miles. This combination of characteristics, high sediment loads mentioned above, and low elevation drops over long distances produce the Mississippi River's meandering pattern. This type of river loops back and forth across a floodplain in an ever changing pattern as the stream flows to the sea. The landforms created by a meandering river are called meander belts. Meander belts are a conglomeration of several landforms, including natural levees, oxbow lakes, distributaries, abandoned channels, point bars, back swamps, crevasse splays, chute cutoffs, and others (Saucier 1994). The meandering Mississippi, Red, Yazoo, Arkansas, Black and other study area rivers are part of a dynamic geological system. The meandering river system is constantly changing the coarse and topography of the region's rivers and their associated landforms.

While the meandering river systems, their depositional formations, and the continental loess and alluvial deposits constitute most of the observable geological features of the central core of the study area, other geological features are also found. These features include the Ouachita Mountains and Crowley's Ridge in Arkansas, the Ozark Plateau in Missouri and Arkansas, the Petrified Forest in Mississippi, and other basins, plateaus, and topographical components.

The Gulf Coast landforms of Louisiana and Mississippi are a product of the sediment dropped at the confluence between the Gulf of Mexico and the Mississippi River. The coastal deltas and coastal landforms are changing bodies of sediment that are constantly being built by the deposition of the Mississippi River and torn down by the erosional effects of the Gulf of Mexico.

Sediment washed along the coast of Louisiana and Mississippi by Gulf wave action have produced the beaches, coastal marshes, and barrier islands found along the study area's coast. Mississippi channel shifts over time have created new coastal areas and left other areas to the erosive power of Gulf waters.

ECOREGIONS

The rich biodiversity of the Lower Mississippi Delta is reflected in the ecoregion provinces designated in the region. The study area encompasses six ecoregion provinces of several thousand square miles each (Bailey 1995). Presented below are general characteristic descriptions of each of the ecoregion provinces including land-surface form, vegetation, soils, climate, and fauna (see Ecoregions map).

Eastern Broadleaf Forest (Continental) Province

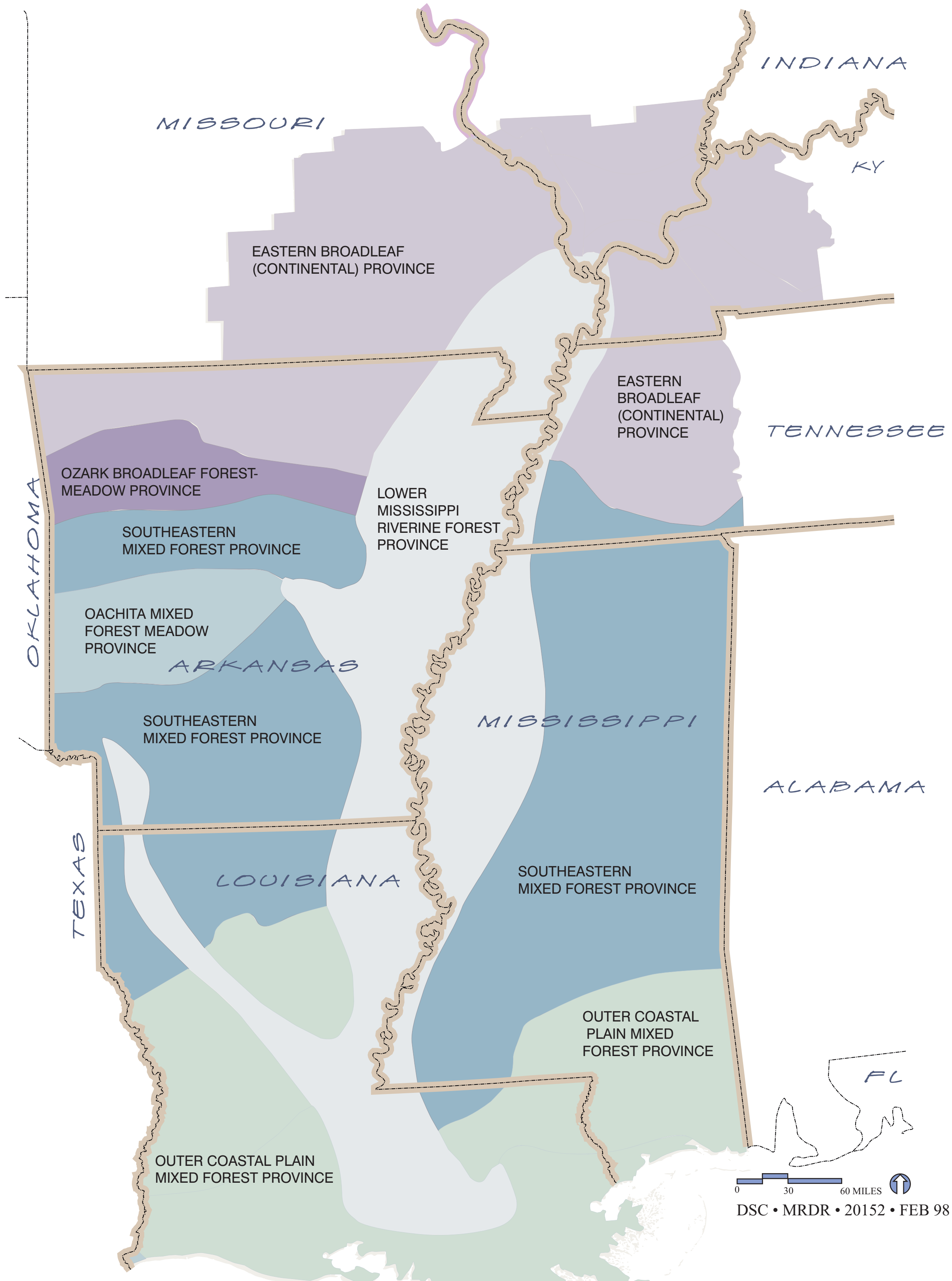
This province characterizes the Ozark Highlands of the northern portion of Arkansas and the western portions of Tennessee and Kentucky. This ecoregion extends beyond the study area and into the northeastern United States. Within the study area the province occupies approximately 46,000 square miles.

Land-surface form. Most of the area is rolling, but some parts are nearly flat, and in the Ozark Highlands the relief is moderate (up to 1,000 ft). Low rolling hills, dissected plateaus, and basins are found in Tennessee and Kentucky. The northern parts of the province have been glaciated in the past but not the southern study area sections. Elevations range from 80 to 1,650 feet.

Climate. The average annual temperatures range from 40°F in the north to 65°F in the south. Summers are hot with frequent tornadoes. Precipitation varies from 20 inches near the 95th meridian to 40 inches in Ohio, and to 50 in Tennessee. Most precipitation takes place during the growing season.

Vegetation. This province is dominated by broadleaf deciduous forest, but the smaller amounts of precipitation found here favor the drought-resistant, oak-hickory woodlands. Although other forests have oak and hickory; only this particular forest association has both species in abundance.

The oak-hickory forest is medium-tall to tall forest. Within the project region the forest forms a mosaic pattern with prairie. Widespread dominants are white oak, red oak, black oak, butternut hickory, and



Lower Mississippi Delta Region

Heritage Study

Eco Regions

shagbark hickory. The understory is usually well developed, often with flowering dogwood. Other understory species include sassafras and hophorn-beam. The shrub layer is distinct with some evergreens. Wildflower species are abundant. Wetter sites typically feature an abundance of American elm, tuliptree, and sweet gum.

Soils. Ultisols are the major soil type found in the study area. As forest soils give way to the darker soils of the grasslands, Mollisols are found.

Fauna. In the oak-hickory forest acorns and hickory nuts provide abundant food for the ubiquitous gray squirrel. Fox squirrels are often found, as are eastern chipmunks.

Roving flocks of blue jays also feed on forest nuts. In summer scarlet and/or summer tanagers, rose-breasted grosbeaks, and ovenbirds are common. The wild turkey is also found here. The cerulean warbler is common in the beech-maple forest and elsewhere.

Ozark Broadleaf Forest-Meadow Province

This province describes the Ozark Highlands in central Arkansas and occupies approximately 5,300 square miles.

Land-surface form. This is an area of low dissected mountains composed of sand-stone and shale, with altitudes up to 2,000 feet and an average relief of 1,500 feet. Valleys are narrow with steep sides and gradients.

Climate. The climate supports moderately cold winters and hot summers. Rainfall is year-round with drier periods in summer and autumn. In Mountain Home, Arkansas, the average annual temperature is 59°F and the average annual precipitation is 41 inches.

Vegetation. This province supports oak-hickory forest. The primary species are red oak, white oak, and hickory. Shortleaf pine and eastern red cedar are important on disturbed sites, shallow soils, and south and west facing slopes.

Soils. The major soils are Ultisols.

Fauna. Birds or mammals are not particularly abundant in this province nor in neighboring ones. Bird and mammal communities are similar to those of the Eastern Broadleaf Forest Province.

Southeastern Mixed Forest Province

This province contains the lands bordering the core of the Mississippi Delta and extends well beyond the study area to the northeast. Within the study area the province occupies approximately 56,000 square miles.

Land-surface form. This province com-prises the Piedmont and the irregular Gulf Coastal Plains. Local relief is 100 to 600 feet on the Gulf Coastal Plains, and 300 to 1,000 feet on the Piedmont. The flat coastal plains have gentle slopes and local relief of less than 100 feet. Most of the numerous streams in the region are sluggish; marshes, lakes, and swamps are numerous.

Climate. Mild winters and hot, humid summers are the rule in this province; the average annual temperature is 60° to 70°F. The growing season is long (200 to 300 days), but frost occurs nearly every winter. Precipitation, which averages from 40 to

60 inches annually, is rather evenly distributed throughout the year but peaks slightly in midsummer or early spring because of thunderstorms. Droughts are infrequent. Snow falls rarely and melts almost immediately.

Vegetation. Medium-tall to tall forests of broadleaf deciduous and needleleaf ever-green trees are dominate in this province. At least 50% of the stands are made up of loblolly pine, shortleaf pine, and other southern yellow pine species, singly or in combination. Common associates include oak, hickory, sweetgum, blackgum, red maple, and winged elm. The main grasses are bluestem, panicums, and longleaf uniola. Dogwood, viburnum, haw, blue-berry, American beautyberry, youpon, and numerous woody vines are common.

Soils. Ultisols dominate throughout the region, with locally conspicuous Vertisols formed from marls or soft limestone. The Vertisols are clayey soils that form wide, deep cracks when dry. Inceptisols on flood-plains of the major streams are among the better soils for crops.

Fauna. Fauna vary with the age and stock-ing of timber stands, percent of deciduous trees, proximity to openings, and presence of bottomland forest types. White-tailed deer and cottontail rabbits are widespread. The fox squirrel is common among decidu-ous trees on uplands. Gray squirrels live along intersecting drainages. Raccoon and fox inhabit the whole region and are hunt-ed in many areas. Among mammals fre-quently encountered in the western part of this province is the nine-banded armadillo.

The eastern wild turkey, bobwhite, and mourning dove are widespread. Of the 20-odd bird species in mature forest, the most common are the pine warbler, cardinal, summer tanager, Carolina wren, ruby-throated hummingbird, blue jay, hooded warbler, eastern towhee, and tufted titmouse. The red-cockaded woodpecker is an endangered species.

Forest snakes include cottonmouth moccasin, copperhead, rough green snake, rat snake, coachwhip, and speckled kingsnake. Fench and glass lizards are also found, as is the slimy salamander.

Ouachita Mixed Forest Meadow Province

This province, which occupies approxi-mately 6,000 square miles, includes the Ouachita Highlands of west central Arkansas.

Land-surface form. The fold mountains here were eroded from sedimentary rock formations compressed into great folds; the upturned edges of the resistant formations form the mountain ridges. The linear ridges reach maximum altitudes of about 2,600 feet, which is approximately 1,500 ft above the adjoining valleys. The folds and the mountains trend east-west.

Climate. The winters are warm and summers hot. Rain falls year-round, but summers are relatively dry. On the outskirts of this province, in Fort Smith, Arkansas, the average annual temperature is 63°F. Average annual precipitation is 41 inches.

Vegetation. The area supports oak-hickory-pine forests. The primary overstory species are southern red oak, black oak, white oak, and hickories. Pine constitutes as much as 40% of the cover (shortleaf pine in the uplands, with loblolly pine on lower lying alluvial soils). The dry sand-stone ridges of the Ouachita

Mountains are covered on their southern slopes by a mixture of shortleaf pine, oak, and hickory, and on their northern slopes by hardwood forests made up mainly of oak and hickory. Hardwoods populate the rich bottomlands of the valleys, and pines predominate on poorer lands.

Soils. The major soils are Ultisols. They are stony and nonstony, with medium textures.

Fauna. Bird and mammal species are similar to those found in the surrounding Southeastern Mixed Forest. One amphibian, the Ouachita dusky salamander, is found exclusively in this province's rocky, gravely streams.

Outer Coastal Plain Mixed Province

This province describes the Gulf Coastal Plains and extends beyond the study area to the east along the south coast of the US. Within the study area the province occupies approximately 34,099 square miles.

Land-surface form. This province comprises the flat and irregular Atlantic and Gulf Coastal Plains down to the sea. Well over 50% of the area is gently sloping. Local relief is less than 300 feet, although some areas are gently rolling. Most of the region's many streams are sluggish. There are also numerous marshes, swamps, and lakes.

Climate. The climate regime is equable, with a small to moderate annual temperature range. The average annual temperature is 60°–70°F. Rainfall is abundant and well distributed throughout the year; precipita-tion ranges from 40 to 60 inches per year.

Vegetation. Temperate rainforest, also called temperate evergreen forest or laurel forest, is typical in this province. Temperate rainforest has fewer species of trees than its equatorial or tropical counterparts, and hence larger populations of individual species. Trees are not as tall here as in low- altitude rainforests; leaves are usually smaller and more leathery, and the leaf canopy is less dense. Common species include evergreen oaks and members of the laurel and magnolia families. There is usually a well-developed lower stratum of vegetation that may variously include tree ferns, small palms, shrubs, and herbaceous plants. Lianas and epiphytes are abundant. At higher elevations, where fog and clouds persist, the trunks and branches of trees are often sheathed in moss. A striking example of epiphyte accumulation at lower elevations is the Spanish "moss" that festoons the Evangeline oak, bald cypress, and other trees of the eastern Gulf Coast.

Along the Atlantic coast, the extensive coastal marshes and interior swamps are dominated by gum and cypress. Most upland areas are covered by subclimax pine forest, which has an understory of grasses and sedges called savannas. Undrained shallow depressions in savannas form upland bogs or pocosins, in which evergreen shrubs predominate.

> *Note:* A word about the vegetation of the coastal Southeastern United States may prevent some misunderstanding. On forest maps of the United States and on numerous maps of world vegetation, this coastal zone is shown as having needleleaf evergreen or coniferous forest. It is true that sandy uplands have forests of loblolly and slash pine, and that bald cypress is a dominant tree in swamps; but such vegetation represents either xerophytic and hydrophytic forms

in excessively dry or wet habitats, or second-growth forest following fire and deforestation. The climax vegetation of mesophytic habitats is the evergreen, oak, and magnolia forest.

Soils. Soils are mainly Ultisols, Spodosols, and Entisols. Temperate rainforest grows on a wide variety of upland soils, but most tend to be wet, acidic, and low in major plant nutrients. The soils are derived mainly from coastal plain sediments ranging from heavy clay to gravel, with sandy materials predominant. Silty soils occur mainly on level expanses. Sands are prevalent in hilly areas, but they also cover broad flats in central Florida.

Fauna. This region provides habitat for a wide variety of animals. Except for a few isolated areas where black bear or the endangered Florida panther are found in small numbers, the white-tailed deer is the only large indigenous mammal. Common small mammals include raccoons, opossums, flying squirrels, rabbits, and numerous species of ground-dwelling rodents.

Bobwhite and wild turkey are the principal game birds. Migratory non-game bird species are numerous, as are migratory waterfowl. Winter birds are diverse and numerous. The red-cockaded woodpecker is an endangered species found in the province.

Of the many species of reptiles found in this province, the American alligator is the largest. Several endemic salamanders are found here.

Lower Mississippi Riverine Forest Province

This province describes the heart of the study area and is synonymous with the cultural and historical concept of the Delta. The Lower Mississippi River Floodplain/ Riverine Forest Province is the only eco-region province completely contained in the study area and occupies 44,302 square miles.

Land-surface form. The province consists of a flat to gently sloping broad floodplain and low terraces made up of alluvium (water transported sediment) and loess (windblown and deposited sediment). From near sea level in the south, altitude increases gradually to about 660 feet in the north. Most of the area is flat, with an average southward slope of less than 8 inches per mile. The only noticeable slopes are sharp terrace scarps and natural levees that rise sharply to several meters above adjacent bottomlands or river channels. This is the land of oxbow lakes and cutoff meanders. Swamps are significant in the extreme southern part of Louisiana.

Climate. Winters are warm, with temperatures ranging from 50° to 60°F, and summers are hot, with temperatures ranging from 70°– 80°F. Rain falls throughout the year, with a minimum amount in autumn. Temperature and precipitation decrease as one moves northward. At Natchez, Mississippi, average temperatures for January and August are about 50°F and 75°F, respec-tively. Average annual precipitation is 55 inches. Snowfall is negligible. Farther north, at Cairo, Illinois, average tempera-tures for January and August are about 41°F and 77°F, respectively. Average annual precipitation is 43 inches.

Vegetation. Before cultivation, this area was covered by bottomland deciduous forest with an abundance of green and Carolina ash, elm, cottonwood, sugarberry, sweetgum, and water tupelo, as well as oak and bald cypress. Pecan is also present, associated with eastern sycamore, American elm, and roughleaf dogwood. Vines are prolific along water courses.

Soils. The soils are a mosaic of Inceptisols (in alluvial bottomland), Alfisols (in areas of loess), and Mollisols (in areas with swampy vegetation).

Fauna. Among the numerous bird species found here are the prothonotary warbler, white-eyed vireo, wood duck, yellow-billed cuckoo, Louisiana water thrush, and all the species found in the Southeastern Mixed Forest Province.

Bottomland Forested Wetlands Within the Study Area

The most influential, unique, and significant province of the Delta's ecoregion provinces is the Lower Mississippi Riverine Forest Province. This province contains the unique bottomland forested wetlands that have had profound impact on the environmental, economic, social, and cultural history of the region.

Two types of bottomland forested wetlands can be found in the Delta region. In inundated areas next to the river Cypress and Tupelo forests dominate much of the year. In dry land areas water oak, willow oak, cottonwood, and other inundation sensitive forest species dominate most of the year. Over 95% of the forested wetlands occur in Louisiana, Arkansas, and Mississippi. The largest contiguous area of forested wetland (approximately 30% of the total in the Delta) occurs in the Atchafalaya basin in the southeastern section of Louisiana.

FOREST RESOURCES

The Delta's forests, hardwood and pine, have been heavily used since the 19th century and very few old growth trees remain. Historically trees have been harvested for the fabrication of railroad cross ties, the rebuilding of Chicago after the disastrous fire of 1871, the construction of the Panama Canal, as well as home furnishings such as cabinets, flooring, moldings, and furniture.

Today the Delta's forests supply pulpwood for paper products (approximately 30% of total production) and saw timber for lumber (approximately 60% of total production). The remaining 10% of products include lumber and chip board, telephone poles, construction pilings, and veneer logs for furniture, cabinets, and other home furnishings.

Demand for specialty tree species for specific markets is high. For example, persimmon logs are used to manufacture golf clubheads, and Paulownia trees (originally imported from Asia) are exported to meet market demands in Japan.

AGRICULTURE

The Delta's fertile soils, temperate climate, and extended growing seasons are a boon to the region's agriculture production. Soybeans, rice, sugar cane, various feed grains, hay, and cotton are produced on study area farms. Approximately 55% and 60% of the land area in the Delta is used for agricultural purposes. Agriculture has a history going back 200 years and has always been important to the economics of the region.

The soils types of the Delta include the soil orders Inceptisols (in alluvial bottomland), Alfisols (in areas of loess), and Mollisols. The primary suborders of soils found are Aquepts, Aqualfs, Udalls, and Udalfs. These soils are deep, moist, and rich in nutrients plants require. The soils commonly need to be drained of water before they can be productive but once drained the land supports high yields of almost any crop. The soils maintain their fertility because the Mississippi River and its tributaries have often flooded, depositing new sediment and replenishing the topsoil. The diverse plants that grow in the Delta are recycled into the soil as a mulch and benefit the soil as natural fertilizer. The soils are free of boulders and gravel, and maintain a sediment size no greater than coarse sand and are easy to cultivate with modern farm machinery.

The climate of the Delta is ideal for farming as large sections maintain moderate temperatures during most of the 200+ days of the growing season. The water supply from the rivers, wells, and annual rainfall seldom leave the Delta short of water for crops. During periods of drought; irrigation systems supply most of the Delta with the water needed for agriculture.

Occasional hurricanes (approximately one every 7 to 15 years) ravage and flood areas of the coastal Delta and may produce damaging effects a few hundred miles inland. These hurricane events cause crop and property damage from flooding, erosion, and high winds; however, the hurricanes are relatively few and the Delta bounces back quickly.

The average rainfall for the area is 45 to 65 inches per year and usually arrives in the form of light to moderately heavy thunderstorms. Snowfall in the region is negligible, and freezing weather is absent in the coastal portions of the study area. Freezing conditions in the northern sections of the study area are confined to a few weeks a year, giving farmers opportunity to grow multiple crops.

MINERAL EXPLORATION AND EXTRACTION

The study area's dominant mineral production is petroleum. Petroleum production is typically confined to Louisiana and the Louisiana Gulf Coast, supplying approximately 90% of the study area's petroleum. The southern portions of Arkansas and Mississippi together add an additional 10% to the production total. While the oil reserves are now becoming depleted, the area continues to produce approximately 200,000 barrels of oil and 270 million cubic feet of natural gas annually. Oil and gas exploration has also stimulated petrochemical manufacturing throughout the Delta.

The production of petroleum and petrochemicals have added to a continuing pollution problem in the Delta. Hundreds of millions of pounds of toxic chemicals are released into the study area every year; for example, 162 million pounds of toxic chemicals were released into the environment in Louisiana in 1994 (State of Louisiana 1996). However, this represents a rapid improvement in the control of toxic waste releases. In Louisiana, toxic chemical releases have dropped from 856 million pounds in 1987 to the aforementioned 162 million pounds in 1994, an improvement of 81%. Similar toxic waste reductions are occurring throughout the region.

Metals mining in the study area is limited to modest iron mining operations. Construction materials such as sand, clay, marble, limestone, and slate, are also extracted and are used locally. There are also moderate salt mining operations located in Louisiana.

FISHERIES

The Mississippi River supports one of the most diverse fisheries in the world. At least 183 species of freshwater fish live in the Delta (Laroe et al. 1995). Minnow, darter, perch, sturgeon, and paddlefish species are among the most common. However; native fish stocks have been declining in number. Approximately 6% of the native fish species in the Delta are found on the endangered, threatened, or special concern lists of the U.S. Fish and Wildlife Service (see appendix C).

The decline of native fish species is a result of the reduced quantity and quality of available habitat. Other specific causes of decline include damming and channelization of the Mississippi and its tributaries, agricultural uses, deforestation, erosion, pollution, and introduced species. It is hoped that implementation of better land management practices and public and governmental programs will restore the fisheries and prevent further degradation of fishery resources.

The region's rivers, numerous lakes, and other water impoundments, support aquaculture, commercial, and sportfishing. While native fish populations have declined, introduced and hatchery-supported sportfish are abundant. Fresh water sportfishing is focused on species of bass, warmouth, sunfish, bluegill, crappie, sturgeon, and catfish. The state fisheries management offices provide for much of the sportfish in the region through fish hatchery production. Coastal saltwater sportfishing is concentrated on the following Gulf species: snapper, redfish, flounder, trout, and pompano. Commercial fishing of finned fish and shellfish in the Gulf of Mexico is centered (in dollars) on shrimp (54% of the total value of all types), menhaden (about 30%), oysters (about 7%), with crab and a variety of other species filling in the remaining 9% of the commercial catch (Kniffen and Hilliard 1988).

Commercially fished freshwater species include: catfish, spoonbill, buffalo, garfish, and other minor species. Commercial fishing has been in a state of decline since the early 1970s. This is primarily due to habitat loss, environmental contamination, and conflicts with navigation.

Aquaculture (fish farming) is growing in importance with the decline in commercial fishing stocks. The main species of farmed fish is catfish. The effects of aquaculture on the Delta's ecosystem is not fully under-stood at this time but is under study by the U.S. Fish and Wildlife Service and various other state agricultural and wildlife agencies.

ENDANGERED AND EXOTIC SPECIES

The Delta, once home to the panther, wolf, and bison, is now facing the extinction of more plant and animal species as natural and man-made processes adversely impact critical habitats across the region. Some of the more widely known endangered, threatened, and species of special concern listed by the U.S. Fish and Wildlife Service include the bald eagle, the peregrine falcon, the Higgins eye mussel, the fat pocketbook mussel, the pallid sturgeon, the Blandings turtle, the Massassaugua rattlesnake, the relict darter, and the Louisiana black bear (see appendix C for a complete list).

The region contains habitat types that are critical to endangered species. For example the Louisiana black bear is primarily found in bottomland hardwood and floodplain forests. Home ranges for black bears vary from 24 to 400 square miles. Various species of mussels depend on unique river bottom conditions for survival. Sustaining viable populations of the various species of threatened neotropical migratory birds depends on maintaining continuous habitat areas along the Mississippi flyway.

Wildlife refuges managed by the U.S. Fish and Wildlife Service and other federal and state-owned properties preserve habitat for endangered and threatened species. Private companies, individual landowners, and special interest groups are trying to create policies to ensure the survival of quality habitat.

Environmentally damaging exotic species have been introduced to the study area, including the nutria (a rodent), zebra mussel and carbicula clams, and 30 species of exotic fish. Damaging plant species such as kudzo, water hyacinth, and purple loosestrife also inhabit the Delta region. These exotic species often replace native species by either directly destroying them or by appropriating their natural habitat. Plants like the water hyacinth and purple loosestrife have severely altered large areas of wetland by replacing valuable native species. The coast and marshes of Louisiana have been severely damaged by nutria, causing soil erosion and marshland plant destruction. Native shellfish and snails are being destroyed by zebra mussel. The zebra mussel and carbicula clams clog municipal water intake pipes.

Eradication programs have been implemented by both federal and state government agencies to suppress many of these exotic species. The result of the eradication programs so far has been mixed; however, with improvements in eradication techniques, successful reductions in exotic species may be possible in the near future.

NATIONAL WILDLIFE REFUGES

Wildlife refuges in the Lower Mississippi Delta Heritage Study Region play a fundamental role in conserving important habitat areas necessary for the survival of animal, waterfowl, and plant species native to the study region. The following federal wildlife refuges are located in the Lower Mississippi Delta Region.

The 25,300-acre **Mark Twain National Wildlife Refuge** consists of nine units in Illinois, Missouri, and Iowa. It plays an important role in providing protected resting and feeding areas for waterfowl along 250 miles of the Mississippi Flyway. Some of the largest wintering concentraions of bald eagles are in the refuge, and more than 220 species of birds use the refuge. The refuge offers wildlife viewing, fishing, hunting, and hiking. Several units provide public boat access.

Clarence Cannon National Wildlife Refuge, which was established in 1964, contains 3,747 acres along the Mississippi River in Missouri. Made up of permanent and seasonally flooded impoundments, forests, grasslands, and crop fields, the refuge serves as another link in the chain of migratory bird refuges along the river. A variety of management techniques are use to enhance habitat diversity, including mowing, disking, limited farming, burning, fallowing, and water-level manipulation.

The 10,428-acre **Reelfoot National Wildlife Refuge** was established in 1941. Reelfoot Lake in northeast Tennessee and southwest Kentucky was formed in 1811 as a result of the most violent earthquake recorded in North America. The formation of the lake created a valuable wetland area that became a haven for many wildlife species and attracted such notable hunters and outdoors men as Davey Crockett and Jim Bowie.

Lake Isom National Wildlife Refuge, 3 miles south of Reelfoot Lake, was established in 1938. The refuge's 1,846 acres of open water, forested wetlands, and croplands are similar in character to those of Reelfoot Lake. The two refuges offer boat access, hunting, fishing, interpretation, and wildlife observation.

Chickasaw National Wildlife Refuge lies along the Chickasaw Bluff in Lauderdale County in western Tennessee. The refuge, established in 1985, is composed primarily of bottomland hardwood forest, but there are also tracts of agricultural lands, locust/Osage upland, and a small acreage of timbered bluffs. The refuge provides habitat for up to 250,000 ducks and is an important wintering and stopover area for large numbers of the Mississippi Flyway mallard population. The refuge offers opportunities for hunting, fishing, hiking, camping, picnicking, and wildlife observation.

Big Lake National Wildlife Refuge occupies 11,038 acres in northeastern Arkansas and southeastern Missouri. It is unique in that 5,000 acres is designated as a national natural landmark and 2,100 acres is included in the wilderness preservation system. The New Madrid earthquake of 1811–12 changed the Big Lake area from a free-flowing river system to the present lake/swamp environment. Like other refuges along the Mississippi, Big Lake is a wildlife oasis in the center of a vast agricultural sea. The refuge offers hunting, fishing, and wildlife observation.

Lower Hatchie National Wildlife Refuge was established in 1980 to preserve a 7,394-acre bottomland hardwood forest tract for wildlife, principally migratory birds. Lower Hatchie, which is administered by Reelfoot National Wildlife Refuge, offers opportunities for hunting and fishing.

The 5,885 acres of **Wapanocca National Wildlife Refuge** lie in one of the last areas in the Arkansas Delta where large concentrations of ducks and geese live. The refuge, which was established in 1961, is composed of equal amounts of bottomland hardwoods, freshwater impoundments, and agricultural land. The refuge is a wildlife habitat island. Nearly every species of duck common to the Mississippi flyway can be found in the refuge, which offers boat access, hunting, fishing, and wildlife observation.

Yazoo National Wildlife Refuge, which encompasses 12,470 acres, was established in 1956. The focus of the refuge, which is managed for waterfowl, is to produce agricultural crops preferred by waterfowl. It includes open agricultural fields and water impoundments.

Saint Catherine's Creek National Wildlife Refuge was established in 1990 to preserve, improve, and create habitat for waterfowl. It encompasses 13,478 acres in western Mississippi 7 miles from Natchez. Habitat consists primarily of cypress swamps and hardwood forests. Restoration of several hardwood species within the refuge is a management objective. The refuge offers fishing, hunting, nature observation, and hiking.

Delta National Wildlife Refuge, located on the southeastern coast of Louisiana, contains 48,800 acres of marsh, shallow ponds, channels, and bayous. It was established in 1935 primarily as a winter sanctuary for migratory waterfowl. It provides winter shelter and feeding and resting places for up to 200,000 ducks and 50,000 geese, including a large wintering population of snow geese. Oil and gas are produced in the refuge. The refuge also offers opportunities for hunting, fishing, and wildlife observation.

THE MISSISSIPPI FLYWAY

The Mississippi flyway is a migratory coarse birds use to travel between South and North America. Many bird and waterfowl species use the flyway for breeding and/or wintering grounds. Flyway waterfowl species include both the blue-winged teal and mallard ducks that nest on islands or in grasslands adjacent to the river. Mallards are the chief species using the Mississippi flyway. Also found in the flyway are eastern prairie populations of Canada geese, snow geese, and lesser white-fronted geese. In addition, many other duck species such as gadwall, green-winged teal, American widgeon, American black duck, and northern pintail are found in the flyway. A number of land and predatory birds, such as the peregrine falcon, Swainson's hawk, eastern kingbird, summer tanager, and yellow billed cuckoo also use the flyway.

Ducks, geese, and swans feed on parts of submergent and emergent aquatic wetland vegetation (seeds, roots, and tubers), as well as invertebrate animals in the wetlands. Farms and aquaculture ponds provide additional foods of fish, corn, rice, and other produced foodstuff waterfowl relish.

The Mississippi Delta is the core of the flyway because of the abundance of wetlands adjacent to the Mississippi River. Over 20% of the nation's duck population feeds and rests along the river during migration. The flyway and its habitat area are essential for the continued viability of the nation's waterfowl populations. Due to its importance, the Mississippi Delta region is a waterfowl habitat area of special concern in the *North American Waterfowl Management Plan* administered by the U.S. Fish and Wildlife Service.

Lands adjacent to the river are a blend of both natural habitats and agricultural lands. Numerous wildlife refuges, along with, and adjacent to, privately held wetland areas, provide additional habitat areas for migrat-ing birds. Hunting clubs, state and local governments, and special interest groups are working cooperatively to save wetland areas.

Federal wetland conservation programs like the U. S. Department of Agriculture Wetland Reserve Program and the U. S. Fish and Wildlife Service Partners for Wildlife and North American Waterfowl are preserving thousands of acres of wetlands. Private organizations like Ducks Unlimited, The Fish and Wildlife Foundation, the National Wetlands Conservation Alliance, and many other groups are actively working to purchase wetland areas or reach cooperative agreements with landowners to save wetland and other natural habitat areas.

LOWER MISSISSIPPI RIVER FLOODS

Background

At Vicksburg, Mississippi, the average flow of water in the Mississippi River is 612,000 cubic feet per second (cfs); however, a flood flow of 2,278,000 cfs or 3.72 times the average flow rate has been recorded (Robinson 1995). The Mississippi River is and has historically been the economic, social, and human development vehicle for the region. No other river has played a more prominent part in the nation's development and expansion.

Life in the Delta is continuously jeopardized by the Mississippi and its natural tendency to flood. From the time of the first permanent European settlements along the banks of the Mississippi River, the most feared word has been "flood." The explorers accompanying DeSoto in 1543 were the first Europeans to see the Mississippi flood. They described the floods as severe and prolonged. LaSalle, exploring the heart of the American wilderness more than a century later, also found the Mississippi on a rampage. New Orleans, founded in 1718, was badly submerged many times in its early history.

Records indicate that great floods of the Mississippi have occurred frequently. Nine great floods were recorded between 1782 and 1850. In 1882, one of the most disastrous floods to that time devastated the entire Delta area of 45,000 square miles. The losses were appalling. Hundreds of crevasses occurred in the weak levees. The breaks in the levees sent floodwaters into populated areas and left thousands homeless. Additional major floods followed in 1912 and 1913.

In 1927 the most devastating of modern floods occurred, inundating an area of about 26,000 square miles, or more than 16 million acres. It was the most disastrous flood in the history of the United States, breaching levees and laying waste to cities, towns, and farms. Property damage amounted to more than $2 billion at today's prices; many lives were lost; and more than 600,000 people were displaced.

After the great flood of 1927, other floods on the Mississippi occurred in 1929, 1937, 1945, 1950, 1973, 1975, 1979, 1983, and in 1993. The interval between major floods on the Mississippi average one every seven years. Large-scale storms that produce floods on the lower Mississippi River occur chiefly during January through April and to a lesser extent in May and June. They are generally a result of extensive and extended rainfall events covering several states within the Mississippi drainage basin.

The primary source of floodwater for the Mississippi River is the Ohio River valley, including the Tennessee River basin. For example, the majority of the 1913, 1937, and 1950 flood discharges at Cairo came from the Ohio basin. More devastating floods like the flood of 1927 developed as a result of a series of storms that produced major runoff over much of the Mississippi drainage basin, including the upper Mississippi and Missouri Rivers. The 1973 flood, the most severe of the more recent floods in the Delta, developed in a manner much like the 1927 flood. Major floods on the upper Mississippi or on the Missouri, Arkansas, and White tributaries generally can take place without a resultant flood on the lower Mississippi River.

The 1993 flood of the Mississippi River had only minor effects in the Delta. However, the majority of historic great floods on the Mississippi have occurred within the lower Mississippi, now protected by the massive Mississippi River and Tributaries project (MR&T). As the crest of the 1993 flood moved into the Lower Mississippi Delta Region of the Mississippi River, flood stages did not exceed bank full. This was due to the river’s greater channel capacity than that of the upper Mississippi and because of the extensive flood control structures located within the study area.

River Flood Control

The three principal stretches of the Mississippi River (upper, middle, and lower) vary significantly in techniques used for flood control. Flooding on the upper Mississippi River basin (from the Mississippi headwaters in Minnesota to the Missouri River confluence) is controlled by numerous man-made reservoirs designed to store up to 40 million acre-feet of floodwater throughout the tributary rivers of the upper Mississippi basin. Developed areas are further protected by a series of levees constructed by both the federal government and private flood control authorities.

The middle Mississippi river extends from the mouth of the Missouri River to Cape Girardeau, Missouri. In this reach, much of the relatively narrow valley is protected against flooding by natural high ground and by a system of levees and flood walls largely constructed by the Army Corps of Engineers. These works protect agricultural lands and control flooding in major metropolitan areas such as Saint Louis, Missouri. Gated drainage structures have been built through levees at some places to permit drainage. At some locations, pumping stations provide interior drainage during floods and when the gates on drainage structures are closed. Tributary projects and flood control dams offer added protection.

Because the lower Mississippi River is where European settlers first experienced the catastrophic floods of the Mississippi River, flood control efforts began within the Delta region, and the struggle between the people and the river has continued to this day.

For almost 300 years the primary defense against floodwaters has been earthen levees. The first levees were small in height and in cross-section, weak, and discontinuous, leaving gaps and openings for the floodwaters to pour through. Even in areas of continuous embankments, levees were often overtopped and crevassed. In the early years of flood control, the basic criteria for levee design (in terms of height and cross-section) was directly related to the height of the prior floods. Levee heights rose and their cross-sections were gradually enlarged as greater floods were experienced.

The first comprehensive effort to gain some understanding of the river’s geology, fluctuations, and pattern of natural change was made in 1860 when Congress authorized a topographical and hydrographical survey of the Mississippi River Delta. This effort resulted in the *Report Upon the Physics and Hydraulics of the Mississippi River, Upon the Protection of the Alluvial Region Against Overflow,* prepared by Captain A. A. Humphreys and Lieutenant H. L. Abbot in 1861. The report analyzed considerable data and discussed various engineering approaches for controlling flooding, including diverting tributaries, constructing reservoirs and cutoffs, enlarging outlets to the Gulf, and building levees. It reported that no flood control advantage could be derived from either diverting tributaries or constructing reservoirs, and that plans for cutoffs and new or enlarged outlets to the Gulf would be too costly and dangerous to attempt. It also recommended that levees could be relied upon to protect all the alluvial valley lands subject to inundation. This approach became known as the "levees only" plan, which shaped the direction of flood control efforts for the next seven decades.

By 1879 the need for flood control improvement on the Mississippi River and coordination of engineering operations through a centralized organization was widely recognized. In that year, Congress established the Mississippi River Commission and asked it to "take into consideration and mature such plan or plans and estimates as will correct, permanently locate, and deepen the channel and protect the banks of the Mississippi River, improve and give safety and ease to navigation thereof, prevent destructive floods, and promote and facilitate commerce, trade, and the postal service." When the duties of the commission were examined closely, it appeared that there was more emphasis on channel stabilization and navigation than on development of flood control works.

The federal government had not declared a federal commitment to flood prevention by appropriating funds to maintain or construct levees. Federal funds could be expended on levees only if a specific improvement could be shown to benefit navigation, such as closing breaks in levees.

In 1882, just three years after the Mississippi River Commission was established, a disastrous flood literally destroyed the existing levee systems. Human losses were appalling, and the outlook for a permanent solution to flooding in the Mississippi valley was thought to be a long way off. In the meantime, work and experimentation continued on ways to control the river. Much of this effort involved developing approaches to stabilize riverbanks, holding the river alignment, and protecting the existing levee system.

Back-to-back floods occurred in 1912 and 1913, again causing havoc on the Mississippi. These floods and another in 1916 convinced Congress to approve a national flood control law. The 1917 Flood Control Act gave the Mississippi River Commission $45 million for flood protection activities. With this new emphasis, levee designs were reviewed and modified, and much-needed construction was expedited. Local interests, while relieved of the total cost burden, were still required to share in the cost of the work. The outlook for dependable flood protection for the inhabitants of the valley seemed more optimistic.

However, the tremendous disaster of the 1927 flood awakened the nation to the need for a comprehensive program to control the giant river, and the 1928 Flood Control Act (since amended many times) authorized the Mississippi River and Tributaries Project, the nation's first comprehensive flood control system. The 1927 flood illustrated that the "levees only" plan was inadequate to control and safely handle the river's flood flows. From numerous plans, Congress adopted the "Jadwin Plan," a group of plans that completely abandoned the "levees only" tradition and replaced it with a comprehensive river regulation system with several distinctive flood control components. The Jadwin Plan and the MR&T projects are designed to safely pass the "project flood," a hypothetical flood which is larger than the record flood of 1927. The hypothetical flood, based on a careful analysis of historical rainfall and runoff data, is about 15% greater in runoff than the flood of 1927 at Arkansas City, a town just downstream from the mouth of the Arkansas River, and 29% greater at Red River Landing, a site about 60 miles below Natchez, Mississippi. The project flood is used as a basis for establishing levee grades and for planning and designing other flood control features such as floodways, reservoirs, and pumping plants.

The four major elements of the MR&T Project are (a) levees that contain flood flows; (b) floodways and control structures that divert excess flows past critical reaches of the Mississippi River; (c) channel improvement and stabilization measures that maintain navigation channel alignments, and help develop an efficient channel for passing flood flows, and protect the levee system from encroachment; and (d) tributary basin improvements that provide for drainage and flood control, such as dams and reservoirs, pumping plants, levees, auxiliary channels, and the like.

The mainline levee system begins on the west bank just below Cape Girardeau, Missouri, and extends (except for gaps due to mouths of tributary streams and high ground) along parts of both sides of the river almost to the Gulf of Mexico. The entire MR&T system of levees is vast. Some 3,714 miles have been authorized, and 2,718 miles are completed. The main part of the system is some 2,200 miles long, 1,608 miles of which extend along the Mississippi River. The rest lies along the south banks of the Arkansas and Red Rivers and in the Atchafalaya Basin.

Floodways were incorporated into the MR&T project to divert excess flood flows from the river's main stem so that levees of reasonable height can be used to contain the project flood.

The Birds Point to New Madrid, Missouri, floodway reduces stages on the Ohio and Mississippi Rivers at, above, and below Cairo, Illinois. The Morganza and West Atchafalaya floodways in Louisiana, along with the Old River structures, are capable of diverting half the project flood into the Atchafalaya River basin. The Bonnet Carré Spillway just upstream from New Orleans diverts flows from the Mississippi River into Lake Pontchartrain to hold down flood stages at New Orleans.

The Old River control structures on the west bank of the Mississippi River, 50 miles northwest of Baton Rouge, were completed in 1962. Their primary purpose is to prevent the capture of the Mississippi by the Atchafalaya River and to regulate flows into the Atchafalaya River and basin. The complex includes a low sill structure and an overbank structure, as well as an auxiliary structure completed in 1986. These structures are used to divert a sufficient amount of water from the Mississippi River to maintain a distribution of 30% of the total latitude flow (the combined flows of the Mississippi and Red Rivers) in the Atchafalaya River and 70% in the Mississippi. There is also a lock and dam on the former Old River channel slightly downstream of the control structures that preserves navigation between the Mississippi River and the Atchafalaya-Red River system. The Morganza flood control structure is about 15 miles downstream from Old River on the west bank of the Mississippi. It is a gated structure built into the levee line that is designed to divert 600,000 cfs of water from the Mississippi into the Atchafalaya floodway.

Channel stabilization and improvement are also an essential part of the flood control and navigation plan. Overall, it consists of stabilizing the banks of the Mississippi to a desirable alignment and obtaining efficient stream flow characteristics for flood control and navigation. Dikes made of rock confine the river to a single low-water channel, reduce excessive widths, and develop desired river alignments for the benefit of navigation.

Revetment, consisting of large concrete blocks joined together with wires, helps stabilize the Mississippi River channel and protect nearby levees by preventing bank caving. Improvement dredging is used to adjust flow patterns, and maintenance dredging deepens shallow channel crossings that tend to form during low water. In the coastal part of the river, foreshore protection (rock structures built lateral to the bank) protect the bank and nearby levees from wavewash attack produced by oceangoing vessels.

During the 1930s and early 1940s a series of cutoffs were created on the lower Mississippi, shortening the river by more than 150 miles. This effort enhanced the flood-carrying ability of the river's channel and reduced flood heights; for example, river stages were lowered by 12 feet at Arkansas City, Arkansas, and 6 feet at Vicksburg, Mississippi. The MR&T project also includes tributary basin improvements such as dams, reservoirs, canals, and pumping plants that provide for flood control and drainage.

EXTRAORDINARY NATURAL EVENTS

The Red River Log Jam

The Red River is headwatered in north-central Texas and travels from the north-west corner of Louisiana to the Gulf on its journey through the Lower Mississippi. In the early 1700s the area's first European explorers discovered the Red River and were hoping to use the channel to navigate upstream. Located approximately at what is now the town of Campti, Louisiana, the explorers found what they described as a raft of dead trees damming the river. The raft or logjams were extensive, causing the river to be unnavigable.

The logjam was created by thousands of trees being undercut at the banks of the Red River further upstream by erosional processes. After the trees were undercut by the Red River and its tributaries, they would float downstream until encountering the upstream end of the logjam and lodge themselves into the massive body of the logjam.

The logjam was approximately 100 miles long and reached a thickness of up to 25 feet in its southern segment (Kniffen and Hilliard 1988). The older sections of the logjam became silted together and were stable enough to create a surface on which plants such as willow could grow on, adding further to the stability and structure of these natural dams. The logjam was not completely continuous and had sections of open water along its length. In areas where tributaries joined the Red River, lakes would form as the added stream flow could not make its way through the natural dam the logjam created.

By the early 1830s the logjam had expanded another 100 miles upstream and continued growing at the rate of approximately 1 mile per year. At the time water transportation was at a premium and was the only cost-effective way to move cotton harvests to the coastal cities for shipment to foreign ports. The Red River would clearly be a valuable navigation route from Texas to the Louisiana Gulf Coast region if a way could be found to remove the raft.

Captain Henry Shreve, superintendent of the Army Corps of Engineers' Western Waters Department, was given what was then regarded as the hopeless assignment of removing the logjam. Shreve used a steam powered snag boat and with his crew, began breaking up the logjam in 1833. By 1838 Shreve had removed enough of the logjam allowing Red River navigation. After completing the initial break up of the logjam, a new logjam immediately formed near Shereveport, Louisiana. Government action cleared the reformed logjam and constant attentiveness has kept a new logjam from forming.

The Red River logjam and its self-created lakes, swamps, and floodplain prairies are unique among river systems in the United States. After the removal of the logjam the natural lakes drained. Many of the valued historic lakes exist today because the former logjam sites have been replaced by dams. The natural ecological systems created by the logjam have fundamentally vanished. The Red River is a regulated river, its floodplain and swamps are no longer being created, and its valuable resources have been used for human recreational and economic purposes. However, there are still places to experience what the logjam environment was like at locations such as Black Lake, Louisiana.

The New Madrid Earthquakes

Immense earthquakes occurred in the Lower Mississippi Delta in the months of December, January, and February of 1811–1812. The two largest shocks probably exceeded the size of any continental earthquake recorded in historical times and were epicentered approximately 32 miles from the Mississippi riverboat town of New Madrid, Missouri (Johnston 1996). Re-search completed at the earthquake center at the University of Memphis, Tennessee, indicates that the three main shocks of the New Madrid earthquakes were equivalent to 8.1 to 8.3 on the Richter scale. At least 18 aftershocks were felt as far away as the Atlantic coast.

New Madrid, located at the intersection of three active geologic faults, was the most significant settlement on the Mississippi River between St. Louis, Missouri, and Natchez, Mississippi, at the time of the earthquakes. European settlements were increasing and the Mississippi River was becoming a major transportation corridor.

To appreciate the magnitude of the of the earthquakes and the resultant effects on the people and environment, the following historic accounts from two eyewitness accounts of the event are included:

> "I happen to be passing in its neighborhood where the principal shock took place . . . the water that had filled the lower cavities . . . rushed out in all quarters, bringing with it an enormous quantity of carbonized wood . . . which was ejected to the height of from ten to fifteen feet, and

> fell in a black shower, mixed with the sand which its rapid motion had forced along; at the same time, the roaring and whistling produced by the impetuosity of the air escaping from its confinement, seemed to increase the horrible disorder of the trees which everywhere encountered each other, being blow up cracking and splitting, and falling by thousands at a time. In the mean time, the surface was sinking and a black liquid was rising up to the belly of my horse, who stood motionless, struck with a panic of terror. . . . These occurrences occupied nearly two minutes; the trees, shaken in their foundation, kept falling here and there, and the whole surface of the country remained covered with holes, which . . . resembled so many craters of volcanics."
>
> . . . about sunrise another very severe one came on, attended with a perpendicular bouncing that caused the earth to open in many places. . . the deepest I saw was about twelve feet. The earth was, in the course of fifteen minutes after the shock . . . entirely inundated with water. The pressing of the earth, if the expression be allowable, caused the water to sprout out of the pores of the earth, to the height of eight or ten feet! The agitation of the earth was so great that it was with difficulty any could stand on their feet, some could not — the air was strongly impregnated with a sulphurous smell (Johnston 1996)."

Because the Delta was sparsely settled by Europeans at the time of the earthquakes loss of life was low, although the exact number of casualties is not known. Many of the tales surrounding the 1811–1812 earthquakes were once thought to be the creation of imaginative minds. However; now, with careful scientific research, many of the fantastic stories of the New Madrid Earthquakes appear to have actually occurred. Some of the events witnessed and reported by victims of the earthquake are include following:

- Extensive and intensive fissuring of the ground surface accompanied by temporary fountains of water mixed with sand. Some of the fountains were huge with dike widths in meters and fissure lengths in kilometers.
- Creation of lakes, primarily Reelfoot in Tennessee; also St. Francis and Big Lake in Arkansas.
- The creation of waterfalls and barriers on the Mississippi River.
- The creation of permanently inundated or sunken forests.
- Native American legends tell of previous catastrophic earthquakes and now evidence exists confirming at least two other major pre-1811 earthquakes in the New Madrid region.
- Eyewitness accounts of the Mississippi River running backwards during the earthquakes. (Johnston 1996)

The New Madrid Earthquakes, the largest earthquake events ever recorded in the continental United States, are an interesting and important part of the Delta's history. Natural relics left from the New Madrid event, like Reelfoot Lake, are fascinating and educational in themselves. Through study of the relics of the 1811–1812 earthquakes, and the related faults located at New Madrid, area universities and government agencies hope to predict future earthquakes and avoid large-scale human and property losses.

ENVIRONMENTAL ISSUES AND CHALLENGES FOR THE FUTURE

At one time the Delta region supported over 20 million acres of bottomland forested wetlands. The pre-European Delta forest was the second largest forested valley in the world, second only to the South American Amazon rainforest. Forested wetlands now occupy approximately 5.5 million acres, a reduction of approximately 72%. The loss of forested wetland habitat and the extensive human manipulation of the natural environment has transformed much of the Delta into an urban and agricultural landscape.

Many of the environmental issues concerning public officials and private citizens in the Delta region arise from a number of sources including; a reduction in forested wetland habitats, the numerous water-control and diversion structures along the river, industrial/petrochemical production facilities, wastewater treatment facilities, and the use of modern agricultural techniques (chemical fertilizers and pest control sprays). The issues related to these sources are poor water quality, extensive soil erosion, pollution of land, air, and water with toxic chemicals, increased flooding frequency, loss of soil nutrients, and reduced biodiversity due to habitat loss.

Toxic chemicals, wastewater, and other types of manufactured pollution have been and are currently being discharged in to the region's waterways. Manufacturing plants and wastewater treatment facilities distributed along the length of the Mississippi and its tributaries are prime sources of pollution. Petrochemical and crude oil discharges occur regularly.

Agricultural runoff, including a mix of fertilizers, herbicides, pesticides, and stockyard waste runoff are major contributors in lowering water quality in the region. As previously mentioned lands are heavily farmed. In some areas more than 60% of available land area is dedicated to agricul-tural uses. The millions of acres of farm-and demand tons of fertilizer, pesticides, and herbicides. These farm chemicals find their way into the Mississippi River and eventually reside in the Gulf.

Agricultural fertilizer runoff has caused increased algae production in both rivers and Gulf coastal areas resulting in the eutrophication of stream and Gulf coast waters. The eutrophication process effectively reduces the amount of oxygen available in the water and leads to the death of animal and plant species that require oxygen.

Petrochemicals released into the Mississippi and its tributaries can and do find their way into drinking water supplies. Concentrations of chemicals used in industry and on farms are seldom removed by water treatment and are consumed by area populations. Contaminants found in drinking water continue to exceed federal safe drinking water standards. (Robinson 1995). The long-term effects of low concentra-ions of these chemicals to both humans and the environment is unknown.

Studies have shown a relationship between increased cancer rates in populations that drink water from the Mississippi River (Costner 1989).

There have also been studies finding people living near petrochemical plants have higher rates of lung cancer (Costner 1989). Cancer rates increase downstream towards the Gulf, with higher incidences occurring in the industrialized areas between Baton Rouge and New Orleans, Louisiana.

The water-control projects on the Mississippi River and it tributaries have led to a decrease in sediment being deposited in the Louisiana coastal delta. Sediment loads that are deposited in the Gulf have decreased by approximately 50% since European settlement. Most of that decrease has come since 1950 (Mead 1995).

The Army Corps of Engineers and other federal and state government agencies are now attempting to increase the amount of sediment transported to the area in hopes of slowing land erosion by the Gulf waters.

Other human interventions such as canal construction, freshwater diversion, and wetland destruction are accelerating the rate of erosion in many areas. Gulf waters are taking over land areas of the coast at the rate of tens of square miles per year (LaRoe, et al. 1995). The land and wetland loss is due to a lack of sediment deposition and the erosive forces of the Gulf. Coastal regions of Louisiana and Mississippi, including many of the barrier islands, marshes, and beaches, are being eroded and inundated by the Gulf. Overall the study area's coastal plain has lost several hundred square miles of land surface to the Gulf.

Balancing socioeconomic needs and environmental health and well being in the Delta presents many challenges. Many of the adverse impacts to the region's natural environment have been viewed as positive and necessary to ensure economic viability of the area.

- Reductions in forested wetlands have given way to cities and land development for human use.
- Water control facilities have channeled the Mississippi and other rivers away from heavily populated areas, saving property and lives from floodwaters. They also provide water for irrigation and domestic use.
- Petrochemical manufacturing and industrial manufacturing have provided employment for the region's residents.
- Agricultural output is phenomenal. Delta farms feed and clothe much of the U.S. and provide significant agricultural exports.

Changes in public attitude toward wildlife and wildlife habitat, increased recognition of the value of clean water, land, and air, and the desire for resolution of serious environmental problems have created a new environmental sensitivity within the Delta. Land and water use has drastically changed across the region. In the past untreated municipal garbage, chemicals, and wastewater were discharged into the Mississippi and its tributaries. Forested wetlands were converted to "useful production" without thought to long term impacts of wetland losses.

Increased awareness of the interconnectedness between humans and their natural environment has led to improvements in agricultural, petrochemical production, and wastewater treatment, and has changed the way water control facilities are operated. Environmental laws such as the *Clean Water Act*, the *Clean Air Act*, and the *Safe Drinking Water Act* together with various federal executive orders, state and local laws, and environmental education programs have led to ever improving environmental conditions.

A general improvement in water quality and a decrease in toxic biological and chemical loads has occurred in the Mississippi waters. Additionally new farming practices reducing or eliminating the need for chemical fertilizers, pesticides, and herbicides are expected to reduce the amount of farm chemicals released into the environment.

New farming techniques such as no-till farming and improved irrigation and crop rotation practices are expected to reduce the rate of soil erosion. Erosion control tools, including wetland creation and riverbank hardening, are being used. Sediment releases from water control facilities are now managed to reduce erosion of lands and coastal areas. Toxic chemical production, use, and disposal are more carefully regulated than in the past. Laws preventing the release of toxic chemicals into the environment have been enacted and enforced.

As knowledge of the natural environment has increased, and the recognized need for habitat preservation has also increased. It is now widely known that forested wetland habitat improves water quality, buffers land from erosion, improves area flood control, and provides for numerous recreational and economic opportunities. Voluntary programs like the Conservation Resource Program, managed by the National Resources Conservation Service and established in 1985 to assist private landowners to convert highly erodible cropland to vegetative cover, are increasing acreage of natural habitat and reducing erosion. The creation of federal, state, and local parks, refuges, and conservation districts is an acknowledgment of the importance of the natural environment and the need to preserve wild places. The study area harbors some of the most spectacular and important natural habitat in the U.S. The multiple efforts of governments and local citizens make the future of the Delta's natural environment look promising.